Guthrie

Great Lakes

THE GREAT LAKES

AND THEIR RELATIONS TO THE

LAKES AND GULF WATER-WAY

BY

OSSIAN GUTHRIE

LAKE FLUCTUATIONS.

BY O. GUTHRIE.

There are at least five distinct fluctuations of the lakes, viz: The annual, the secular, or irregular, atmospheric, tidal, the oscillations of impulse and those of rest, and also one or more current movements.

The object of this paper is to present to the reader these several movements of the lakes, with other interesting facts and phenomena and explain some of them from a standpoint of over forty years of practical observation and study.

ANNUAL FLUCTUATIONS.

These fluctuations, occur as regularly as the changes of the season, and average about fifteen inches at Chicago, the lake generally reaching the highest level in July, but sometimes as early as May, and again as late as September. Like all others, they are common to all of the Great Lakes, but are unequal in extent, the range increasing in their order from 1.2 at Superior to 1.9 at Ontario—Michigan and Huron being on the same level except as they are affected by unequal atmospheric pressure. (According to observations taken at all stations around the lakes by Mr. L. E. Cooley, C. E., of the Chicago Drainage Commission, on one occasion in 1886, several inches of water temporarily disappeared from Lake Michigan during a protracted storm.) In view of the proposed "Lakes and Gulf Water-way," the wisdom of which has been semi-officially challenged, these fluctuations are very important;

but aside from this they are interesting and valuable in aiding us to determine the source of supply of the lakes and to explain other phenomena.

At the Peoria Convention, October 11–12, 1887, Major Thomas H. Handbury, Corps Engineers U. S. Army,* read an elaborate paper on the "Illinois River Improvement," some of the statements in which appeared to the writer as ill-considered; and as a friend of the Major's characterized the statement of which I am about to speak, "a slip of the tongue." About the time the present Congress convened, a pamphlet entitled "Illinois River Improvement—Some facts in relation thereto," was distributed among the members. This pamphlet, to the public, is of unknown paternity. On page 9 is the following extract from Major Handbury's Peoria paper:

"In treating of this question of drawing a large supply of water from Lake Michigan, there is one point of great importance that I do not find touched upon in any of the reports or discussions upon the subject; that is the effect that the withdrawal of so large a quantity of water from Lake Michigan as is proposed by the Chicago Drainage Commission, is going to have upon the mean level of the lake.

The discharge of the upper lakes through the St. Clair River has been found to be about 217,000 cubic feet per second. The mean level of Lakes Huron and Michigan is 581 feet above the level of the sea; that of Lake Superior about 20 feet higher. The lower lakes receive their supply from this upper lake, and the various streams that empty into them. This discharge is just equal to the supply, and the lakes remain at their mean level of 581 feet."

*Major Handbury stated that it was not an official document.

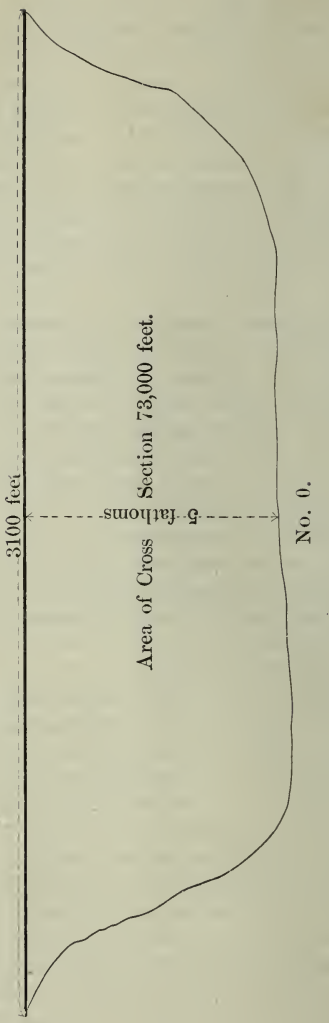
"Now, suppose we make another outlet in the *bottom* (the italics are mine) or side, if you please, of this lower reservoir capable of taking $^1/_{20}$ of this supply, which is the amount it is proposed to withdraw, what is going to happen in time to the mean level, to the depth of water in the various harbors and to the channel of the St. Clair River, which the government is spending so much time to improve? This is a question upon which the people at the other outlet of the lakes may wish to have something to say."

The Major's hypothetical question neither inspires the average mind with a belief in its honesty of purpose, or strikes the engineer as showing good sense. It has never been proposed to make another outlet either in the bottom or side, but in the brim of the dish, on the same level, and of about the same depth, as the natural outlet.

Under such circumstances it must be obvious to the average mind that when the flow through the natural outlet has been reduced by an amount equal to the full capacity of the artificial channel—about 4 per cent.—the reduction of level must cease.

Diagram No. O shows a cross section of the St. Clair River at a point where its channel width is about 2,500 feet and average depth 30 feet. The upper side of the heavy line representing the surface shows the normal condition of that river, and the lower side of the line, the theoretical condition after the maximum effect of the new channel shall have been reached according to the calculations of Mr Cooley.

According to the theory advanced in this paper, taking into consideration the counteracting influences of the annual fluctuations, a point above the centre of this line would represent the extreme effect on navigation.


3100 feet
5 fathoms
Area of Cross Section 73,000 feet.
No. 0.

Robert E. McMath, C. E. of St. Louis, in his paper read before the Engineers' Club of St. Louis, May 30, 1888, entitled The Waterway between Lake Michigan and the Gulf, after considering the supply and natural outflow of the St. Clair River, and the size of and proposed outflow through the Desplaines channel, reaches the conclusion "that it would require 4.45 years to lower Lakes Huron and Michigan one foot, or at the rate of 2.7 inches per year.

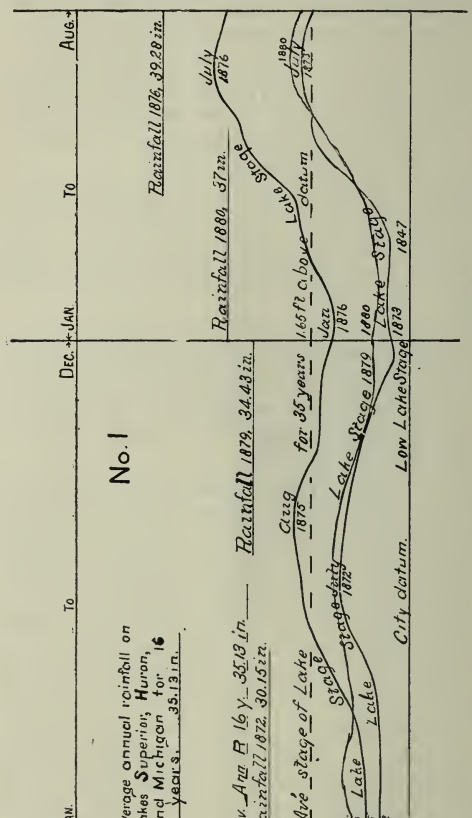
The conclusion is therefore safe that the effect will not be noticeable, except as a result of a long series of observations, such as was required to establish the fact of a tide in the lakes."

Mr. McMath's paper, by reason of his peculiar experience is one of the most valuable papers published upon this subject, and should be read by all interested parties. The Citizens' Association of Chicago has several hundred copies for distribution.

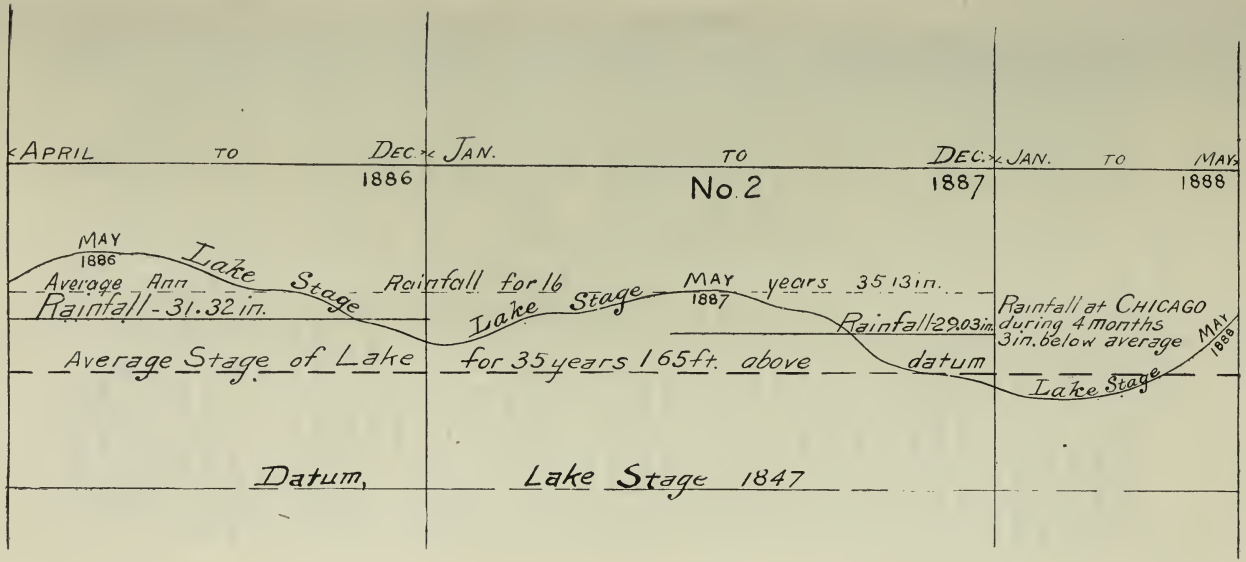
Mr. Cooley, whose extensive experience entitles his opinion to the highest consideration, in his comprehensive brief on the Lake and Gulf Water-way, shows that the annual reduction would not exceed 2.78 inches, and the maximum, independent of counteracting influences, would not exceed five; but even this figure, inconsiderable as it is by comparison, will be materially reduced, as will be shown hereafter.

The diagrams No. 1 and 2 herewith will aid the reader to compare the fluctuations with the rainfall and show him at a glance some of the characteristics of nearly every year of the thirty-five in the whole series. They are drawn to scale from monthly means of a record of lake fluctuations at Chicago, since 1854. They are also drawn to scale in reference to rainfall except the heavy line in No. 1 relating to the average for sixteen years, which, to avoid com-

plicating the details, was placed too high. The dotted line above 1872 indicates its true position in reference to datum. These lines repre-



sent the rainfall at all the United States signal stations around Lakes Superior, Huron and Michigan, and are made from signal service reports. Datum at Chicago, (the base line in both diagrams) was established by the trustees


APRIL TO DEC. 1886
JAN. TO DEC. 1887
JAN. TO MAY 1888
No. 2
MAY 1886
Lake Stage
Average Ann. Rainfall - 31.32 in.
Rainfall for 16 years 35.13 in.
MAY 1887
Lake Stage
Rainfall 29.03 in.
Rainfall at CHICAGO during 4 months 3 in. below average
MAY 1888
Lake Stage
Average Stage of Lake for 35 years 165 ft. above datum
Datum, Lake Stage 1847

of the Illinois and Michigan Canal in 1847, and is supposed to represent the lowest water of that year. It is about 0.7 of a foot below Milwaukee datum. Although this line has been frequently crossed, no monthly mean has since been so low within 0.5 of a foot. The years represented in these diagrams have been selected because they were representative. Those of No. 1 show nearly the extremes of both annual and secular changes, and No. 2 shows the same changes in very nearly an average form.

The reasons why the level of the lakes would not be lowered, as theoretically indicated, particularly with reference to navigation, are these: While it is obvious that with the proposed channel open, the lake would not rise so high in summer, it is also clear that it would not begin to fall until about August, and during the succeeding five months of navigation would only fall about 1½ inches more than they would do in their normal conditions.

The time when the proposed channel would produce the greatest effect upon the lake would be during the winter, but the flood waters of spring, instead of going to waste in excessive outflow from Lake Huron as they now do, like flood water over a mill dam, would first fill the void occasioned by the new channel; then, again, heavy rains upon large areas of lake water shed, would still further neutralize the effect of that channel. By reference to diagram No. 1, it will be seen that the rainfall in 1876 was above mean, exceeding thirty-nine inches, and that the lake had risen 2.2 feet by July, thus increasing the outflow from Lake Huron above its normal condition by more than four times the capacity of the proposed channel.

There is in the basin of the Kankakee River within the State of Indiana an area of over 1,600 square miles which is now tributary to the

Illinois, but which is sufficiently elevated to flow into Lake Michigan. The rainfall upon this great area contributes its quota to the floods in the Illinois, as does also the rainfall upon over 600 square miles in the Desplaines basin, above the proposed Bowmanville diversion. The diversion of these flood waters to Lake Michigan, together with the influences above referred to, would so far overcome the effects of the proposed channel, that years of careful observation would be required to detect any change in the lake level, if, indeed, any change could ever be detected. But the impounding of a reserve of five inches of water in Lake Superior, alone, would overcome any effect of the proposed channel.

That five, or even twelve inches of water could annually be held in reserve, needs no argument to demonstrate. Again, Charles Crosman, Civil Engineer of the United States Engineer's office, at Milwaukee, Wis., in his "Chart of the Great Lakes," page 3, estimates that they contain 6,000 cubic miles of water, and says:

"Perhaps a better idea of this volume may be obtained when it is said that it would sustain Niagara Falls in its present condition for about 100 years."

This estimate applies to all the lakes; Superior, Huron, and Michigan could only respond to such a call about ninety years; but the writer, pinning his faith to the heretofore unfailing source of supply, and particularly to our increasing knowledge in utilizing the bounties of nature, allows his inherent selfishness to dictate that he ignore the interests of posterity and dismiss this subject, in the belief that his interest will have long since lapsed, when trouble from this source begins. It has also been urged that Canada might not consent to the diversion of so large a volume of water. The

proposed Lake and Gulf water-way would promote the interests of the continent, and no "dog-in-the-manger" policy, if it would, should be allowed to even retard it.

Canada will want water for her enlarged Welland, and her proposed Georgian Bay Canals; we will join her in an effort to store away enough for all purposes.

SOURCE OF SUPPLY.

The source of supply of the Great Lakes has occasioned much speculation, and in the minds of many is involved in mystery. Wonder is excited in the mind of the visitor at Niagara; he can hardly conceive the source of supply of this mighty cataract. In round numbers an average of 25,000 barrels of water, of forty gallons each, annually falls on every square acre of area within the basins of these lakes—16,000,000 of barrels on every square mile, and there are 231,000 square miles. The latest authorities give the outflow from the lake basins at one cubic foot per second, per square mile. This would be equal to thirty-seven million cubic feet of water per minute, but as about five-eighths of this rainfall is evaporated and carried away by its nebulous appendage which stretches away in the distance a thousand miles or more, only about 2,600,000 of barrels per minute are tumbling over the cataract.

Subterranean sources are by many believed to exist; but when we know that the rainfall exceeds the outflow by more than two to one, and that the frosts of winter never fail to reduce, nor the rains and melting snows of spring to raise the level of the lakes, we have no difficulty in reaching the conclusion that their source of supply lies within reach of these influences, and consequently could not be subterraneous.

SECULAR FLUCTUATIONS.

These secular fluctuations may be said to be constant in either their upward or downward movement, but irregular in duration, rapidity and range, their extreme range, independent of atmospheric changes, being about four feet. They have occasioned much more speculation, and seem to be involved in much more mystery than either the annual or atmospheric changes. The frequency with which the idea is advanced, that they recur at regular periods of seven or nine years, seems to indicate that the subject is still little understood. In 1884 the writer endeavored to show that they were governed by rainfall, and the data then at hand seemed to sustain that theory beyond question; but the data furnished by the years 1886, 1887 and thus far in 1888, while sustaining it in an independent series, do not fully harmonize with that furnished in 1872, 1876 and 1879; for the reason that the same rainfall seems to have had a much greater effect on the lakes in 1886 and 1887 than 1872 and 1879, as will be seen by reference to the diagrams.

EFFECT OF FORESTS ON HUMIDITY OF CLIMATE.

While the effect of forests on rivers and lakes may yet be considered an unsettled question, it seems to be generally conceded that forests augment the flow of streams. That the lake basins were denuded of their original forests in a very large proportion during the fourteen years from 1872 to 1886, would not seem to admit of doubt, but, notwithstanding this, the lakes show a much higher stage from a rainfall of 31.32 and 29.03 inches in 1886 and 1887 respectively than they did in 1872 and 1879 from 30.15 and 34.43. This is a fact beyond question, and should go far toward quieting the nerves of those people who are passing sleepless nights lest our lake commerce be destroyed by

the Desplaines channel. The question is, have the lake basins really been denuded? Throughout the forests destroyed by the fires of 1871, small trees now protect the ground, apparently, far better than it was originally protected; but does forest protection protect? Brown, in "Forest and Moisture," cites instances where marshes have been dried by forests.

On Michigan avenue, in Chicago, there are several hundred elm trees averaging about nine inches in diameter and thirty feet high, with small tops; each of these trees, in addition to the rainfall and what they get from a lawn bountifully watered every day, require twenty gallons of water daily for three months. My own experience with elm trees fourteen to sixteen inches in diameter and forty to fifty feet high, leads me to believe that they would use, if they could get it, over 100 gallons a day. The subject of forest and moisture is entirely too complex a question for discussion here, and is only suggested in the hope that it will, in connection with all other studies relating to the lake and gulf water-way, receive the most careful and thorough investigation by Congress.

The *Forum* for June published an article on the "Changes of Level of the Great Lakes," from the pen of Prof. G. K. Gilbert, in which he adopted the same theory as the writer did in 1884. Elisee Reclus, a French writer and compiler, in "A New Physical Geography," published by Appleton in 1886, also attributes these changes to unequal rainfall. Charles Crosman, C. E., heretofore quoted, in his chart of the lakes, has platted the lake fluctuations and rainfall from the time of the first continuous observations to date. This chart shows that heavy rainfalls and high stages of lake, (and vice versa), generally coincide, but

not always. Notwithstanding the anomalies presented by a comparison of the diagrams, which represent two series of years, No. 1 showing three rising stages within a period of seven years, and No. 2 a falling stage covering a part of three years, the evidence seems conclusive that the secular changes are the result of heavy or light rainfalls as the case may be, and generally coincide with them; and the exceptions, or the anomalies presented above, may be accounted for by the difference in effect upon streams and lakes between light and frequent rains, or heavy and less frequent, the quantity being the same, together with the difference in evaporation, which seems from the few observations taken, to vary as widely in proportion as does the rainfall in different years or periods. Observations by D. Farrand Henry on evaporation from the surface of Lakes Huron and Michigan in 1867 and 1868 showed a variation of 25 per cent. between those years. The water from light and frequent rains, in a large proportion, would be exhausted to supply a continuous evaporation from the surface of the land, leaving a small proportion to reach the streams, while that from heavy rains would, in a much larger proportion, either find its way directly into the streams or sink into the earth beyond the reach of the sun, to make their flow more continuous. The belief is confidently entertained that when observations, more in detail than heretofore, are made in relation to the quantity, character and locality of rainfall, and evaporation, much of the phenomena and mystery concerning the lakes will have been explained.

In relation to the secular fluctuations recurring at regular intervals of time of seven or nine or any other number of years, there is no foundation whatever for such a belief as will

be obvious from a study of diagrams No. 1 and No. 2; for instance, from 1872, when the lake was the lowest since 1847, to 1876, when it was the highest, except one year, 1859. Again, compare 1875 and 1876, which show a wide range in the stages of consecutive years. Then again, referring to the lake stage of 1879, in No. 1 we find the stage the lowest average except 1872, since 1847. Following this line to July, 1880, we find that it had crossed the line of average stage for thirty-five years. From 1880 to 1887 the lake stage was continuously high, but began to decline in August, 1886, and continued to decline until March, 1888, apparently the result of deficient rainfall; the rainfall of 1886 being only 31.32 and that of 1887 29.03, a deficiency of about ten inches in the two years.

The long immunity from low lake stage which vessel owners had enjoyed, and the construction by them of a large number of mammoth vessels, of greater capacity even than the high lake stage would allow to be fully utilized, had illy prepared them for an inevitable recurrence of the low stage. Undue alarm has been created among them lest the lakes were undergoing a permanent change; and this alarm has given occasion for many newspaper articles not calculated to allay it. If the reader will observe the line showing the lake stage of 1888, and notice the sharp upturn in April and May (at this writing, July 12, the lake is still rising, and to-day shows 2.6 feet above city datum, with a light wind from the north which probably raised the water about four inches), he will find ground for belief that there is little danger of even reaching the low stages of 1872 and 1879, much less that a permanent change is taking place. However, to prognosticate what will or will not take place in this respect, is simply guessing at the weather.

ATMOSPHERIC FLUCTUATIONS.

These fluctuations are local and do not, like the annual and secular fluctuations, affect the average level of the lakes, the water being high at one point, while it is correspondingly low at another. They are occasioned by changes in atmospheric pressure, and the effect of these changes is increased in varying degrees, according to its velocity, by the friction of the wind on the surface of the lakes, and hence have a wider range than that directly resulting from atmospheric pressure upon the surface. Wind is the natural result of change in atmospheric pressure, and is generally preceded several hours by a change in lake level, which is a very reliable indication of approaching wind. (The effect of friction will be more fully shown under the head of "Currents of the Lakes.") These changes are known as Seiches on the Baltic Sea and Lake Geneva, Switzerland. Elisee Reclus, heretofore quoted, says: "Schulten has proved that the Seiches of the Baltic, which are in every respect similar to those of Lake Geneva, are in direct connection with the barometric column."

TIDAL FLUCTUATIONS.

Mr. Crosman, heretofore quoted, says: "The tidal change at Chicago, as determined by United States survey, had an amplitude of 1½ inches for neap tide and about three inches for spring tide."

CURRENTS OF THE LAKES.

There is a constant but imperceptible movement in all the lakes in the direction of their outlets. The wind always produces two currents, a surface current in the direction of the wind, and a return or under current, practically in the opposite direction.

The velocity and depth of the surface current varies with the velocity and duration of the wind. The under current, in its general direc-

tion, is in the line of easiest return to the points whence the surface current is supplied The effect of these currents upon the range between atmospheric fluctuations in shallow and deep lakes is significant. For example, Professor Whittlesey is quoted by Mr. Crosman as saying: "That a northeast gale reduced the water-level at Buffalo, N. Y. on the 18th of August, 1848, to a point 15½ feet lower than the surface of the lake, on Oct. 18, 1849, at which time a terrible gale occurred from the southwest. The widest range ever known on Lake Michigan has probably never exceeded seven feet, thus showing that through the friction of the wind on the surface, and great depth of the surface current during heavy gales on Lake Erie, far more than to the direct effect of atmospheric pressure on the surface, is due the wide range in this class of fluctuations. A fluctuation of this class, far more memorable than those above quoted, occurred at Buffalo in 1844, the destructive effects of which to life and property the writer witnessed. A terrific gale sprung up during the night, and the water rose so as to drown between forty and fifty persons in their beds; two were drowned in Huff's Hotel on Main street. Just how high the water rose on this occasion is not known.

On the 5th of August, 1885, a rare opportunity for observing wind current was presented at Chicago. On the second of that month there was a rainfall of over six inches. Thirteen million tons of water, it was estimated, fell within the corporate limits of the city within thirty hours. This vast volume, augmented by the overflow from the Desplaines River, rushed in a torrent into the lake, where it remained undisturbed until the morning of the 5th, at which time the turbid waters occupied not less than ten square miles of area, with outlines as well

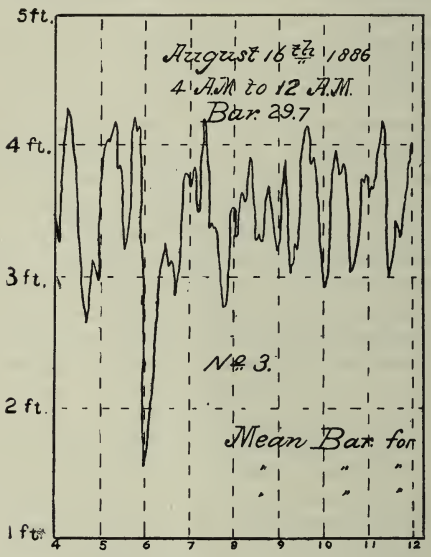
defined, almost, as though it were a solid. About 7 o'clock A. M. a very light due east breeze sprung up and the heretofore expanding area of turbid water, apparently began to contract, until, by 10 o'clock, no trace of it could be seen outside of the breakwater. A sheet of blue lake water deep enough to hide the turbid mass had been driven by the wind over its entire surface, but the lake water was not so deep but that a tug wheel would bring the turbid water to the surface and leave its wake plainly marked. Turbid blotches now began to appear as far lakeward as the eye could reach, but north and south the turbid area had not enlarged so rapidly. By 12 o'clock the turbid blotches had increased in number and size until they covered an area of not less than fifty square miles, but the color was not so dark as before its disappearance. By 7 P. M. the mingled waters had extended northward until they surrounded the crib.

Aside from these well defined currents which can be traced to cause, the lakes seem to be in a state of almost constant unrest; even in times of perfect calm currents are found wandering about aimlessly and, so far as our limited observations show, without cause. Mr. L. E. Cooley, civil engineer of the Chicago Drainage Commission, on one occasion in 1886, observed a current of three-quarters of a mile per hour in a northeasterly direction from the Chicago harbor; the prevailing current, however, contrary to public opinion, was found to be northward, although accretions form on the north side of all piers and shore obstructions.

The writer is indebted to Captain George C. Almy, United States officer in charge of the harbor work at Chicago, for the following from his report of Jan. 1, 1884: "Among the principal causes tending to protract the labor of re-

building these cribs was the surprising frequency and strength of the currents, making it often impossible to keep the scows in place or the drivers at work.

"Great fluctuations of the lake level naturally accompanied changes in the direction of



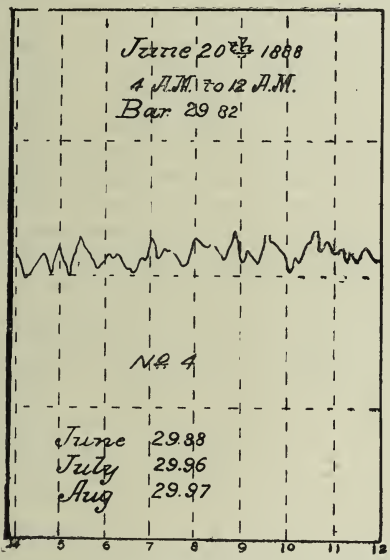
the current, the gauge showing a rise or fall of from two to three feet within an hour. No explanation of this phenomenon has been attempted by any one, and, so far as known, no record exists of anything of the kind of equal magnitude."

OSCILLATING FLUCTUATIONS.

There seem to be two distinct fluctuations of this character and they appear to be incessant, one or the other, in their influences on the level of the lakes. They appear to result from different causes, but possess some similar characteristics, although they differ widely in degree;

the larger one, that of unknown impulse, at comparatively long and varying intervals of time, usurping the functions of the smaller and showing rapid changes in lake level entirely beyond the influence of any possible variation in atmospheric pressure.

Diagram No. 3 shows fluctuations of this character which occurred Aug. 16, 1886, and



also, all the atmospheric changes tending to produce them. On the 23d of July, 1884, fluctuations of this character occurred, ranging from plus 4 feet to minus 0.15, equal to 49¾ inches. The barometer at 7 A. M. read 29.92. At 3 P. M., 29.96, and at 10 P. M. 29.87. Mean barometer for the month being 29.96. Wind changeable, N., S. W., and West; velocity 21 miles, fifteen and one mile per hour respectively. A fluctuation of this character occurred at Cleveland a few years since in which, it was reported, the

lake level changed five feet. Also, at Marquette, Mich., July 11, 1888, "at 7.30 this evening a dense cloud passed over the city and out over the lake. It was not felt on the ground. The water in the harbor fell 26 inches in a few minutes. The lake and bay were calm at the time. After 33 minutes the water returned again. It is believed a cyclone passed near here." [From a telegram of that date.]

NORMAL CONDITION OF THE LAKE.

The oscillations of rest, the smaller oscillations shown in Diagram No. 4, appear to represent the normal condition of the lake to be a state of unceasing fluctuation; they precede or follow the great oscillations regardless of their impulse or influence, showing the same range through several consecutive days. Diagram No. 4 also shows the atmospheric condition of June 20, 1888, when the lake was the most quiet of any day in the month, the whole month, until the 28th, being remarkable for its almost unbroken calm at Chicago. These fluctuations, as also those of August 16, 1886, were recorded by an automatic gauge. It is presumed the fluctuations shown in this diagram are such as Mr. Crosman referred to in his "Chart of the Lakes." He says: "Whenever the lakes are sufficiently free from the disturbing action of the winds to permit observations, a quite regular series of small waves, or pulsations can be detected, which have an interval of about ten minutes from impulse to impulse." While the oscillations shown in this diagram are all within a range of five inches, it is difficult to detect anything like the regular intervals of time mentioned by Mr. Crosman.

FLUCTUATIONS OF TEMPERATURE.

The temperature of the water in the lakes never gets below 32 degrees Fahrenheit, and

rarely exceeds 70, an extreme annual range of 38 degrees, while that of the atmosphere frequently reaches 110 and sometimes exceeds 120 degrees. At 39.4 degrees water attains its maximum density, and in the fall as its temperature begins to recede at the surface it sinks or mingles with the water below, and this process is continued until the entire body has reached that temperature. After that, as the weather grows colder, the surface assumes a temperature of 32° and, by reason of its lighter specific gravity, if undisturbed, slowly by comparison, imparts this temperature to the water below, until the surface is covered with ice, when this process is reversed, and during hard freezing weather the tendency is for the temperature to rise or return to about 39°. Nature seems to have ordained that about this degree of heat should be stored away and maintained. This wise provision is a special blessing to the habitant of the east shore of Lake Michigan and the south shore of Lake Erie; and in general a blessing to all lovers of delicious fruits, for, without doubt, it is to the modifying influence of this equable temperature of the water in the lakes, far more than special adaptability of soil, that we are indebted for the variety, perfection and abundance of Michigan and the almost unequaled quality and supply of grapes from the south shore of Lake Erie. Statistics of this grape production are not at hand, but suffice it to say that the extent of the grape culture on the south shore of Lake Erie is almost beyond belief. As before stated, nature seems to have ordained that this agreeable temperature be maintained, for in the formation of ice (always from water at 32 degrees) 140 degrees of latent heat is rendered sensible, and to a great extent transmitted to the water below,

and should the body of water be entirely covered with ice and the freezing process continue long enough, the temperature of the entire body would be raised to about 39 degrees; and the colder the weather the sooner the change will take place. During a thaw, as the process of liquifaction goes on, the body of water beneath the ice grows colder until a temperature of about 34 degrees is reached, at which point it will remain as long as it is covered with ice. The normal temperature of ice is 32 degrees, but during extreme cold weather its temperature will largely conform to that of the atmosphere. Some standard authorities say that water, when kept perfectly quiet, may attain a temperature of 20 degrees (12° below the freezing point) without crystalization. The writer has never been able to reduce water in its natural condition below 32 degrees.

THE CHICAGO DIVIDE.

Professor Gilbert, heretofore quoted, says: "It is probable that the surplus waters of the Superior and Ontario escape over the lowest points of their rocky rims, but if the drift were removed at the south end of Michigan the lake would find a lower outlet and become tributary to the Mississippi." This statement is not in accordance with local lore.

Let the reader imagine himself a passenger on a Chicago and Alton Railroad train starting from the Union Depot at Chicago, with a seat on the right-hand side of the car. At a distance of about two miles he will cross the Chicago River, but a few feet above its surface, almost within reach of a long-handle dipper. About two miles further along he will cross the South Fork of that river on the same level. Except in times of freshet this river stands at lake level. As he proceeds on his journey beyond Brighton Park and toward

Grand Trunk crossing, if he will look northward he will notice a very conspicuous white building a little more than a mile away. This is a great stone crushing establishment and stands upon a rocky prominence on the north side of Mud Lake Valley, the bed of the northern branch of the ancient outlet of Lake Michigan. This rock dips rapidly to the south and soon disappears beneath the bed of Mud Lake. On its eastern slope it is polished so smooth as to be difficult to ascend; on its crest, rudely scratched and carved in glacial hieroglyphics is plainly recorded the direction whence these monsters came, and also that of their onward march. Some of the glacial boulders lie prone and meaningless upon its ragged crest, while others are at the end of an abruptly terminated groove, the lines of which exactly conform to their own shape. It was the writer's good fortune a few years since to visit this interesting locality after a large area had recently been stripped of the soil, but the boulders still remained. In one instance the rude graver, after cutting its way for quite a distance, had been stopped in its further progress and remained in exactly the position in which it was left countless ages ago. This rocky eminence, the first to be met, seems to come within the scope of Professor Gilbert's statement.

While I have been indulging in this, perhaps excusable digression, our train has emerged from the Lake Basin and is now at Summit Station, at the head of the ancient outlet of Lake Michigan, the valley of the Desplaines River. This valley averages about one mile in width, and the indications are that its ancient flow was from twenty to thirty feet in depth. At present, there are in the thirteen mile level, from Ogden Dam to Lemont, along which we are now passing, long stretches of pools having

from twelve to twenty feet of water, four to twelve feet below datum. The next stop we make is at Mt. Forest, sixteen miles from Chicago. Near here, upon the high ground, perhaps thirty feet or more above datum, is a deposit of as pure lake sand as can now be found on the lake shore. This deposit was so extensive as to induce parties to lay a tramway to the canal for the purpose of shipping sand to Chicago, but it was found too expensive and was discontinued. Almost directly across the valley and at about the same elevation is another deposit of sand which is now supplying the town of Lyons with building sand. Passing Willow Springs Station we reach Sag Bridge, and are now crossing the southern branch of the ancient outlet of Lake Michigan, at its junction with the Desplaines River, and seventeen miles distant from the Calumet River at Blue Island. This valley and that of Mud Lake, in elevation are almost exactly alike, but their geological formations are unlike, the Sag throughout almost its entire distance being rock. Just before reaching Lemont, two miles below Sag Bridge, we pass Walker's quarry. At this point we reach the first rock barrier to the southern outflow of Lake Michigan. It is only 7 feet above present stage of lake and 9 feet above datum, but slopes rapidly, dropping about 33 feet in 9 miles. This rock barrier, it is believed, extends quite around the south end of Lake Michigan, but it is buried a hundred feet or more beneath the drift. It appears to crop out again at Momence, on the Kankakee River, at an elevation of 28 feet above Lake Michigan.

RESUME.

Reviewing the northern or Chicago divide from its beginning at a point on the west branch of the Chicago River, five miles from

its mouth, to which point it is now navigable for large vessels, the distance to Lockport is only 28 miles, and the highest point is only 12 feet above datum, and that only for a short distance, and at the lowest point 12 feet below. There are short stretches of morainic deposit along the 13-mile level, reaching nearly to the water's surface, but it is believed no solid rock worthy of notice will be found above datum until we reach Lemont. This, as before stated, begins at 9 feet above datum and drops to 24 below in nine miles. In short, notwithstanding it tends to disprove the statements of Professor Gilbert in the *Forum*, if an average were struck in the elevation of the divide, Lake Michigan would to-day, to a considerable degree, be tributary to the Mississippi.

LAKE DATA.

From Charles Crosman's "Chart of the Lakes."

LAKE.	Area of Water Surface. Square Miles.	Aggregate Area of Basin. Square Miles	Maximum Depth in Feet.
Superior.....	31,200	82,800	1,008
Michigan	22,450	60,150	870
Huron.....	23,800	55,500	750
Erie.....	9,960	32,660	210
Ontario	7,240	28,840	738

"The drainage basin of the Great Lakes (shown in Fig. 1; omitted) is a reduction of a careful compilation of the best authorities," etc. "It shows also that while the line of deepest water does not coincide with the middle line of lakes, it does approximately with the medial line of lake basin. It will further be observed that, with the exception of Lake Erie, the points of greater depth quite nearly coincide with the centre figure of each basin. This is believed to be a fact never before noticed."

TRANSFERRING THE CENTER OF TRADE.

Chicago is the trade center of the civilized world. To overcome the inertia of this trade center would be a stupendous task, one which will never be undertaken.

Suppose Joliet should have a small number of ore-laden vessels discharge their cargoes into the smelting furnace of the Joliet Steel and Iron Co., would Chicago be the loser? No, because Chicago is the distributing center of that company, it does its banking here and here its general office is located. A few years since an effort was made in this city to transfer the trade from South Water street to a more roomy and convenient locality. For this change there seemed to be an urgent need, South Water street was then and is now one of the most inconvenient and unpleasant trade centers in Chicago, and the locality to which it was proposed to transfer its trade in every respect its superior; but in its infancy trade had become worsted there and a change involved a preparation of a more attractive home for a large majority of the traders; and nothing short of this could accomplish the change. Experience taught the few who tried the experiment that they could not leave the trade center though they had rent free and their accommodations superior in every respect.

Chicago is the natural center of a wheel, of which her rapidly multiplying and extending arteries of trade are the radii and for the rim of which, the material even, is not yet being considered. In its inhabitants, Chicago is cosmopolitan and the industries of the civilized world are represented here. Change this trade center? No! As well try to deflect the earth from its orbit.

SEWAGE DILUTION.

To the Joint Special Committee appointed to investigate in relation to the effect of Chicago Sewage upon the rivers through which it passes:

Gentlemen:—You will recollect that at your

	Running time in min's	Cubic ft per min.	Population	Cubic feet per min. per 100,000 inhb's	Remarks.
1860.					
June 31 to July 31	9,171	12,000	109,000	11,009	
Aug. 1-31	4,891	8,257	"	7,575	
Sept. 3-26	3,011	14,000	"	12,844	
1861.					
June 23 to Aug. 31	23,100	11,000	124,000	8,800	
1862.					
May 28-31	2,810	18,000	138,000	13,000	
June 22-30	5,390	12 000	"	8,834	
July 1-19	16,703	13,400	"	9,700	
1863.					
July 5-31	15,710	12,500	153,000	8,170	
Aug. 1-31	16,430	10,500	"	6,860	
Sept. 1-30	10,915	10,000	"	6,500	
Oct. 1-15	About like Sept.			6,500	
1864.					
June 11-30	11,900	10,800	169,000	6,400	This year
July 1-16	13,995	10,000	"	5,900	showed the
Aug. 11-31	15,395	10,600	"	6,200	first deposit
Sept. 1-30	Same as August			6,200	of sludge in
Oct. 1-31	About			4,000	the canal.
1865.					
May 29 to Oct. 25, inclusive,			290	934,000	Irregularly.
1866.					After this date
June 7-30	24,480	10,000	200,000	5,000	irregular.
1867.					This pumping
June 19-30	15,840	12,340	225,000	5,500	was in excess
				or an ave'ge	of the needs of
				5,041	Chicago.
July 1 to Nov.				ave'ge	Lockport mill-
15	198,720	13,000	"	5,500	ers wanted the water.

meeting of March 31, Mr. J. D. Paige, representing the delegation from Joliet, contended that no benefit would be derived from dilution. In reply to my question, he said that no disagreable effects were ever experienced until after the deepening of the canal in 1871, and in this position he seemed to be supported by

the whole delegation, or at least was not contradicted by a single member. My object in questioning Mr. Paige was to lay the foundation for introducing the above table showing the operation of the Bridgeport pumping works from 1860 to 1867 inclusive.

The pumps were operated to the close of the year 1870.

This record shows, particularly that in 1867, for a period of five months almost the entire sewage of Chicago, (the city then containing 225,000 inhabitants,) was sent down the canal diluted by 5,500 cubic feet of water per minute for each 100,000 inhabitants, and passed Joliet unnoticed, as shown by her own delegation it had done. To a greater or less extent, Chicago sewage, it was also shown, had, since the opening of the canal in 1848, passed Joliet; much of this time, by reason of long delay in starting the pumps, the Chicago river was in as offensive a condition as it has ever been since. This evidence, with that of Mr. Paige undisputed, viz : that no inconvenince was ever felt until after the deepening of the canal in 1871, seems conclusive, that sewage may be so diluted as to be inoffensive to the senses. In addition to the degree of dilution shown above, the flow of the Desplaines river was then uninterrupted, and summer packing, which now contributes largely to the river pollution, was unknown.

O. GUHRIE.

IN CONCLUSION.

In presenting this table and combatting the position of the Joliet delegation before the last Legislature, the writer does not mean to say that the people of Joliet and others along the canal and river have had no cause for complaint, but quite the contrary; but he does

mean to say that the good faith of Chicago, if not her good judgment, was shown beyond question when she expended voluntarily $3,000,000 in deepening the canal. This scheme, for the defeat of which the writer used his best efforts, upon grounds since fully verified as correct, was projected by a near neighbor of Joliet, and in a financial if not sanitary view, Joliet as well as Lockport has realized by the deepening of the canal.

That the people along the canal and river should take measures to guard against a repetition of the canal scheme is as commendable in them as it is wise in the people of Chicago. We are in full accord with them in this respect. A few individuals, "at or near Chicago," as well as along the line, have opposed the Lake and Gulf Water-way project, some for one cause and some for another,

Let me state a few fundamental propositions.

1st. The Desplaines river water, neither with or without Chicago sewage would be potable.

2d. That river and the Illinois, like all rivers, are the natural receptacles of the sewage and drainage of their valleys.

3d. They have now at times in addition to their natural burden, to carry the entire sewage of Chicago, at all times the great bulk of it; and whatever may be the outcome, whether the canal is operated or the Desplaines water-way be substituted for it, this is inevitable.

Admitting these self evident propositions, the people from Chicago to the Gulf will be benefited in a greater or less degree, as the flow of pure lake water is increased; and the people from Chicago to the mouth of the Illinois will be especially benefited. At no point on the globe are there greater attractions to engage the attention of public spirited individuals, or to excite the enterprise of capital-

ists than we see in the project before us, and which now only awaits legislative action and the opportunity to make the beginning of this great work an accomplished fact, and its early and successful completion only a question of a few years time. On the latter point the writer speaks advisedly.

A few words to the opponents of the Lake and Gulf Water-way:

The natural and inevitable result of the efforts of its promoters will be the removing of all obstructions to a flow of 600,000 cubic feet of water per minute from the Mississippi to a point within a few miles of Chicago; thence two branches to Lake Michigan. The great project promotes the interests of both its branches and the private interests connected therewith. Natural and obvious advantages plainly indicate which will be first completed; but the necessity of the early completion of the other is none the less obvious. Let the good work go forward.

APPENDIX.

"COMING EVENTS CAST THEIR SHADOWS BEFORE."

By the time the Lakes and Gulf Water-way shall have been completed, Joliet, from present indications, will be as deeply interested in the purity of the water of Lake Michigan as Chicago. Then we shall have a superannuated canal, which would be a tempting bed for a conduit to supply Joliet with pure lake water.

THE SANDS OF LAKE MICHIGAN.

The geologist could easily cover pages with interesting and instructive matter in relation to the sands of the lakes; but as the writer is not a geologist and sand, except indirectly, being foreign to the subject, but little space will be devoted to its consideration. It cannot be denied, however, that in handling the drainage

and water-way question heretofore, "sand" has been, and perhaps still is, conspicuously deficient in some conspicuous individuals. This, seemingly, is not as it should be where sand abounds.

Since the last glacial epoch, the sands of Lake Michigan have shortened its length about ten miles, created four rivers, obliterated some of them and changed others; made forced marches and counter-marches with them, aggregating, perhaps, 150 miles; changed a lake area of 400 square miles to land, and buried to an average depth of ten feet, what, by reason of numbers, might almost be termed a forest, of prostrate oak along the lake shore, furnishing sites for some of the most imposing structures on the continent. Changing the subject, Chicago must have perfect drainage and pure water, and the nation must provide better lake defense. To secure these, she must have not only the co-operation of the people along the line of the proposed drainage channel, through the state, and along the Mississippi, but largely of the nation. Nothing short of the magnitude of the Lakes and Gulf Water-way will accomplish this. If unfounded individual opinion antagonizes this, the individual, not the project, must be changed.

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